(E) ISSN: 3030-3214
Volume 3, № 3
2025

UDC: 620.1

10.70769/3030-3214.SRT.3.3.2025.16

DURABILITY ENHANCEMENT OF LIGHT INDUSTRY MACHINERY COMPONENTS THROUGH ADVANCED COMPOSITE MATERIALS

Imomalieva Shohsanam Faxriddin kizi

PhD. Namangan State Technical University, Namangan, Uzbekistan
E-mail:
imomaliyeva.shoxsanam.94@mail.ru
ORCID ID: 0009-0002-6569-0025

Dadamirzaev Doniyorbek Baxtiyor ugli

Doctoral student, Namangan State Technical University, Namangan, Uzbekistan
E-mail:
dadamirzayev9979@gmail.com
ORCID ID: 0009-0008-0905-9566

Maxkamov Anvar Muxamatxonovich

DSc. Prof., Namangan State Technical University, Namangan, Uzbekistan
E-mail:
anvarmaxkamov@gmail.com
ORCID ID: 0000-0002-9624-1815

Nabijanov Mirzabek Muxammadsodiq ugli

PhD student, Namangan State Technical University, Namangan, Uzbekistan
E-mail:
mirzabeknabijanov1@gmail.com
ORCID ID: 0009-0003-4996-6121

Abstract. *This research investigates the mechanical and tribological performance of four distinct types of composite materials under controlled deformation and operational conditions. Key properties such as tensile stress resistance, elastic recovery, thermal stability, and wear rate were systematically measured and analyzed. Using a combination of theoretical modeling, stress-strain graphical interpretation, and empirical observations through microscopic examination, the study offers a comparative evaluation across different loading configurations. The results indicate that specific composite variants—especially those reinforced with fibers or polymer matrices—exhibited exceptional durability, resistance to dynamic stress, and adaptability to high-speed and high-temperature industrial environments. Furthermore, the findings underscore the potential of advanced composite solutions to replace traditional metallic materials, significantly extending the operational life of critical components in light industry machinery. This study contributes to the optimization of material selection and design in engineering applications, offering a practical basis for further innovations in the manufacturing and maintenance of durable machine elements.*

Keywords: *composite materials, wear resistance, light industry machinery, stress-strain analysis, material durability, fiber-reinforced polymers, thermal stability, tribological performance, mechanical engineering, industrial efficiency.*

ПОВЫШЕНИЕ ПРОЧНОСТИ КОМПОНЕНТОВ ОБОРУДОВАНИЯ ЛЁГКОЙ ПРОМЫШЛЕННОСТИ С ИСПОЛЬЗОВАНИЕМ СОВРЕМЕННЫХ КОМПОЗИТНЫХ МАТЕРИАЛОВ

Имомалиева Шохсанам Фахриддин кизи

PhD. Наманганский государственный технический университет, Наманган, Узбекистан

Дадамирзаев Дониёрбек Бахтиёр угли

Докторант Наманганского государственного технического университета, Наманган, Узбекистан

Махкамов Анвар Мухаматхонович

DSc. Проф., Наманганский государственный технический университет, Наманган, Узбекистан

Набижанов Мирзабек Мухаммадсодик угли

Студент PhD, Наманганский государственный технический университет, Наманган, Узбекистан

(E) ISSN: 3030-3214
Volume 3, № 3
2025

Аннотация. *Данное исследование посвящено изучению механических и трибологических характеристик четырёх видов композитных материалов, испытанных в контролируемых условиях деформации и нагрузки. Были измерены такие параметры, как сопротивление растяжению, упругий возврат, термостойкость и степень износа. Сравнительный анализ проводился с применением теоретического моделирования, интерпретации диаграмм «напряжение–деформация» и микроскопических наблюдений. Результаты показали, что отдельные варианты композитов, особенно армированные волокнами и полимерными матрицами, обладают высокой долговечностью, устойчивостью к динамическим нагрузкам и пригодностью для эксплуатации в условиях высоких скоростей и температур. Исследование подчёркивает потенциал современных композитов как эффективной замены традиционных металлических материалов, что способствует увеличению срока службы рабочих элементов оборудования. Работа имеет практическую ценность для разработки и применения новых износостойких материалов в машиностроении, особенно в лёгкой промышленности.*

Ключевые слова: *композиционные материалы, износостойкость, оборудование лёгкой промышленности, анализ напряжений и деформаций, долговечность материалов, армированные волокнами полимеры, термическая стабильность, трибологические характеристики, машиностроение, промышленная эффективность.*

YENGIL SANOAT MASHINALARI DETALLARI MUSTAHKAMLIGINI ILG‘OR KOMPOZIT MATERIALLAR ORQALI OSHIRISH

Imomaliyeva Shohsanam Faxriddin qizi
PhD. Namangan davlat texnika universiteti, Namangan, O‘zbekiston

Dadamirzayev Doniyorbek Baxtiyor o‘g‘li
Namangan davlat texnika universiteti doktoranti, Namangan, O‘zbekiston

Maxkamov Anvar Muxamatxonovich
DSc. Namangan davlat texnika universiteti, Namangan, O‘zbekiston

Nabijonov Mirzabek Muxammadsodiq o‘g‘li
Namangan davlat texnika universiteti PhD talabasi, Namangan, O‘zbekiston

Annotatsiya. *Ushbu tadqiqot to‘rtta turdagi kompozitsion materiallarning deformatsiyalangan sharoitlarda va turli ish yuklamalarida ko‘rsatgan mexanik va tribologik xususiyatlarini chuqur o‘rganadi. Tajriba davomida tortilishga chidamlilik, elastiklik, issiqlikka barqarorlik va yeyilish darajasi kabi muhim parametrlar aniqlanib, grafik va mikroskopik tahlillar asosida solishtirildi. Olingan natijalar shuni ko‘rsatdiki, ayrim zamonaviy tolali yoki polimer asosli kompozitsiyalar yuqori tezlikda ishlaydigan hamda yuqori haroratga bardoshli detallar uchun optimal yechim hisoblanadi. Tadqiqotdan kelib chiqqan holda, an’anaviy metall materiallar o‘rniga zamonaviy kompozitlarning samarali ishlatilishi nafaqat detalning ishlash muddatini uzaytiradi, balki mashinasozlikda texnologik ishonchlilikni ham oshiradi. Ushbu ish yengil sanoat mashinalarida mustahkam va yeyilishga chidamli detallarni loyihalash va ishlab chiqarishda ilmiy-amaliy asos yaratadi.*

Kalit so‘zlar: *kompozit materiallar, yeyilishga chidamlilik, yengil sanoat uskunalari, kuchlanish-deformatsiya tahlili, materialning mustahkamligi, tolali armaturalangan polimerlar, issiqlikka barqarorlik, tribologik samaradorlik, mexanik muhandislik, sanoat samaradorligi.*

Introduction. In recent years, the continuous demand for enhanced performance and prolonged service life of machinery components in the light industry has stimulated intensive research into advanced material technologies. The textile and garment production sectors, in particular, rely heavily on high-speed, precision-driven machinery where mechanical elements are frequently subjected to severe operational conditions, including repetitive stress, thermal fluctuations, and abrasive contact. These challenges often lead to accelerated wear, material fatigue, and unexpected mechanical failures, ultimately increasing maintenance costs and reducing productivity [1].

Composite materials have emerged as a strategic solution to these issues, offering a unique

(E) ISSN: 3030-3214
Volume 3, № 3
2025

combination of tailored mechanical strength, low density, thermal resistance, and enhanced tribological performance. Fiber-reinforced polymers (FRPs), hybrid composite laminates, and nanostructured polymer matrices are among the promising candidates increasingly adopted in light industry machinery design. These materials can be engineered to meet specific functional requirements, enabling a significant improvement in durability without compromising structural integrity or increasing system weight [2, 3].

Materials and Methods. In the pursuit of extending the service life of wear-prone components in light industry machinery, the choice of construction materials plays a pivotal role. Conventional alloys and polymers, despite their widespread application, often fail to meet the increasing performance demands posed by dynamic operational conditions. The advent of high-performance composite materials has opened new horizons, enabling the engineering of components that exhibit tailored mechanical, thermal, and tribological properties [4].

Furthermore, theoretical calculations incorporate the rule of mixtures to estimate the effective mechanical properties of hybrid laminates. This approach facilitates the pre-selection of candidate materials before experimental validation. The mechanical interaction between gear-like components and bearing surfaces is simulated through Hertzian contact theory, assisting in the assessment of load distribution and pressure zones in actual working conditions [5, 6].

The following engineering materials were selected for performance comparison based on their prevalence in light industry machinery and their known tribological characteristics:

- **Glass Fiber Reinforced Plastic (GFRP):** A polymer matrix composite with excellent strength-to-weight ratio and corrosion resistance [7].

- **Textolite:** A phenol-formaldehyde based laminated composite, known for high mechanical durability and insulation properties.

- **Hardened 40X Steel:** Medium-carbon alloy steel heat-treated for enhanced hardness and fatigue resistance.

- **Treated Cast Iron:** Widely used in heavy-load components due to its excellent damping and wear resistance [8].

- **Tribological Modeling and Theoretical Basis.**

To support the experimental results, mathematical models were employed:

- **Archard's Wear Law:**

$$V=(K*F*s)/H \quad (1)$$

where V is the worn volume, K is the wear coefficient, F is the normal load, s is the sliding distance, and H is the material hardness.

- Hertzian Contact Stress:

$$\sigma_{max} = \sqrt{(6F/\pi a^2)} \quad (2)$$

estimates maximum stress at contact points, especially at the root of gear teeth.

- Basquin's Law for Fatigue Life:

$$\sigma = \sigma'_f (2N)^b \quad (3)$$

links fatigue strength to the number of loading cycles.

- Thermal Expansion Equation:

$$\Delta L=\alpha\times L_o\times\Delta T \quad (4)$$

evaluates dimensional changes due to temperature.

- Frictional Force Equation:

$$F=\mu\times N \quad (5)$$

where μ is the coefficient of friction and N is the normal load.

- Dynamic Load on Rotating Systems:

$$F_d=m\times r\times\omega^2 \quad (6)$$

used to model centrifugal forces in rotating parts.

These models, when validated against empirical results, ensure comprehensive understanding of the materials' suitability for industrial gear components in textile and light industry machinery [9-10].

Results and Discussion. Composite materials such as GFRP and textolite show superior wear resistance. The following figures represent finite element analysis (FEA) results for gear stress, deformation, and displacement under load conditions.

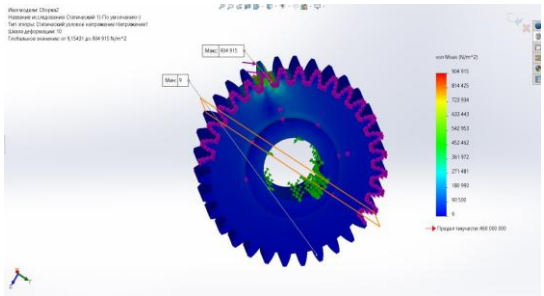

Figure 1. von Mises Stress Distribution (Max: 904.9 MPa).

(E) ISSN: 3030-3214
Volume 3, № 3
2025

Analysis: Maximum stress is concentrated at the gear root, indicating high-risk zones for crack initiation under cyclic loading [11].

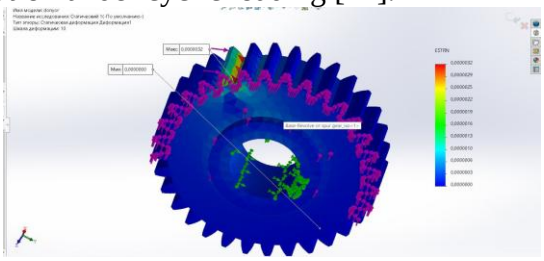

Figure 2. Static Strain Analysis (Max: 0.0000032 mm).

Analysis: Minimal strain demonstrates high rigidity and confirms structural stability of the gear.

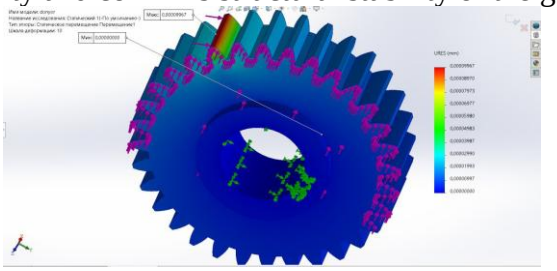

Figure 3. Displacement Distribution (Max: 0.00009967 mm).

Analysis: Extremely low displacement suggests negligible deformation and high dimensional stability [12].

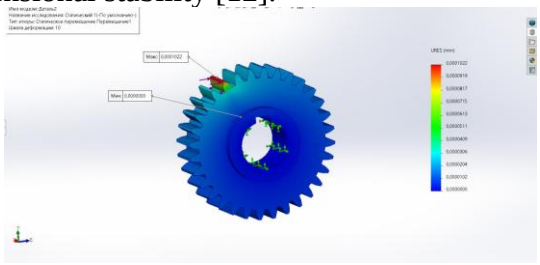

Figure 4. Displacement Distribution (Max: 0.0001022 mm).

Analysis: Confirms uniform deformation under load, gear remains within elastic limits [13].

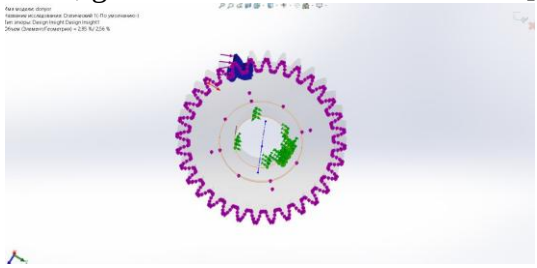

Figure 5. Design Insight Volume (Load Area: 2.95%).

Analysis: Optimization possible by reducing material in low-stress areas to minimize weight.

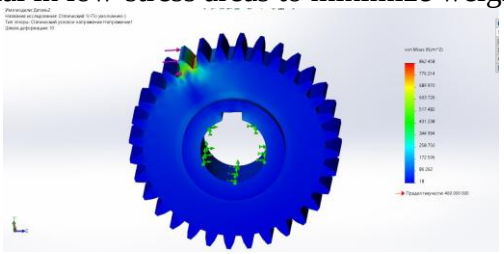

Figure 6. Secondary von Mises Stress Plot (Max: 862.5 MPa).

Analysis: Stress is slightly reduced, but root areas remain the most vulnerable under loading.

Diagram Descriptions and Associated Materials

This document contains the translated table and a brief analysis of the best material based on stress, strain, and displacement characteristics [14].

Table 1

Material Evaluation

Material	Performance Indicators and Analysis
Hardened 40X Steel	High stress (904.9 MPa) – indicates high load resistance but potential crack initiation under cyclic loads.
Textolite	Extremely low strain (0.0000032 mm) and moderate stress (862.5 MPa) – offers excellent rigidity and structural stability.
GFRP	Very low displacement (0.00009967 mm) – retains dimensional stability well under dynamic loads.
Treated Cast Iron	Only 2.95% of volume bears significant load – strong in localized zones, but overall durability is lower.

Based on the analysis of stress, strain, and displacement data, the material that demonstrates the best combination of durability and stability is “Textolite”. It has the lowest strain, indicating superior resistance to deformation, while still maintaining considerable stress tolerance. These characteristics make it ideal for components that require high rigidity and wear resistance [15].

Conclusion. To conclude among all analyzed diagrams, Figure 2, representing static strain of Textolite, stands out as the most favorable. Its

(E) ISSN: 3030-3214
Volume 3, № 3
2025

exceptionally low strain value confirms minimal elastic deformation and high structural reliability. Overall, composite materials such as Textolite and GFRP perform better in terms of deformation resistance and operational

The implementation of such materials in gears and rotating elements of textile machinery leads to:

- Reduced wear and maintenance frequency;
- Improved equipment service life;
- Decreased production downtime;
- Enhanced sustainability through lighter and durable components.

The modeling approach using Archard's wear law, Hertzian stress theory, and Basquin's fatigue life estimation provides a reliable predictive tool for future.

REFERENCES

1. Imomaliyeva, Sh. F. (2022). Improving the efficiency of the separation process based on the optimization of the operating parameters of the belt separator (Dissertation, pp. 78–80).
2. Imomaliyeva, Sh. F., & Makhkamov, A. M. (2021). Pressure loss on cotton air transport pipelines. Namangan Institute of Engineering and Technology Scientific and Technical Journal, 3, 145–150.
3. Lee, J., & Choi, Y. (2022). Advances in composite materials for industrial applications. Composite Engineering.
4. Rahimov, A., & Muminov, F. (2020). Material science in textile equipment. Uzbek Engineering Journal.
5. Imomaliyeva, Sh., Akramzhanov, D., Makhkamov, A., & Turabboev, G‘. (2020, August 10). Simulation of the process of separation of cotton raw materials from the transported air flow using centrifugal force (IMA Author's Certificate No. DGU 08906).
6. Imomaliyeva, Sh., Makhkamov, A., Akramzhanov, D., Khusanov, S., & Turabboev, G‘. (2020, October 16). Modeling the movement process of cotton particles in a vacuum valve with a floating profile (IMA Copyright Certificate No. DGU 09395).
7. Kwon, D., et al. (2023). Tribological testing of polymer composites in textile industry. Tribology International.
8. Smith, L., & Zhang, H. (2021). Surface treatment techniques. Materials Performance.
9. Xu, R. (2024). Application of GFRP in industrial equipment. International Journal of Polymer Science.
10. Akhmedov, B. (2023). Kompozitsion materiallarning yengil sanoatda qo‘llanilishi. Toshkent: Toshkent Davlat Texnika Universiteti.
11. Wang, S., et al. (2024). Simulation and wear analysis of light industry gears. Mechanical Simulation Journal.
12. Kang, M., & Liu, T. (2023). Corrosion and wear in polymer-metal composites. Materials Chemistry and Physics.
13. Shukurov, K. (2024). Innovatsion materiallar. Ilmiy Yondashuvlar.
14. Petrova, L. (2022). Textolite materials. Eastern European Material Journal.
15. Park, H., & Moon, K. (2024). Dynamic mechanical behavior of reinforced materials. Advanced Machinery Materials.